

Chapter 17

Organizing Life's Diversity

What You'll Learn

- You will identify and compare various methods of classification.
- You will distinguish among six kingdoms of organisms.

Why It's Important

Biologists use a system of classification to organize all living things. Understanding classification helps you study organisms and their evolutionary relationships.

Understanding the Photo

All of the living organisms in this photo can be classified by biologists. Classification allows living things to be organized according to shared characteristics and how closely related they are to each other.



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- review content with the Interactive Tutor and self-check quizzes



Section 17.1

Objectives

Evaluate the history, purpose, and methods of taxonomy.

Explain the meaning of a scientific name.

Describe the organization of taxa in a biological classification system.

Review Vocabulary

species: a group of organisms that can interbreed and produce fertile offspring (p. 7)

New Vocabulary

classification
taxonomy
binomial nomenclature
genus
specific epithet
family
order
class
phylum
division
kingdom

Classification

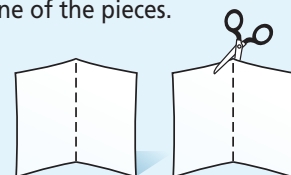


Classification Systems Make the following Foldable to help you summarize and sequence the classification systems.

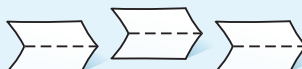
STEP 1 Fold two vertical sheets of paper in half from top to bottom.



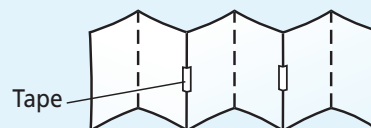
STEP 2 Turn both papers horizontally and cut the papers in half along the folds. Discard one of the pieces.



STEP 3 Fold the three remaining vertical pieces in half from top to bottom.



STEP 4 Turn the papers horizontally. Tape the short ends of the pieces together (overlapping the edges slightly) to make an accordion book.



STEP 5 Label each fold.

Sequence As you read Chapter 17, arrange the classification systems from oldest to youngest beginning at the far left of the Foldable. Then, write a description of each classification system on the appropriate fold.

Word Origin

taxonomy from the Greek words *taxo*, meaning to "arrange," and *nomy*, meaning "ordered knowledge"; Taxonomy is the science of classification.

How Classification Began

Organizing items can help you understand them better and find them more easily. For example, you probably order your clothes drawers and your CD collection. Biologists want to better understand organisms so they organize them. One tool that they use to do this is **classification**—the grouping of objects or information based on similarities. **Taxonomy** (tak SAH nuh mee) is the branch of biology that groups and names organisms based on studies of their different characteristics. Biologists who study taxonomy are called taxonomists.

Aristotle's system

The Greek philosopher Aristotle (384–322 B.C.) developed the first widely accepted system of biological classification. He classified all the organisms he knew into two groups: plants and animals. He subdivided plants into the three groups, herbs, shrubs, and trees, depending on the size and structure of a plant. He grouped animals according to various characteristics, including their habitat and physical differences.

Word Origin

binomial nomenclature from the Latin words *bi*, meaning "two," *nomen*, meaning "name," and *calatus*, meaning "list"; The system of binomial nomenclature assigns two words to the name of each species.

If you analyze the basis for Aristotle's groups, you can see it was useful but did not group organisms according to their evolutionary history. According to his system, birds, bats, and flying insects are classified together even though they have little in common besides the ability to fly. As time passed, more organisms were discovered and some did not fit easily into Aristotle's groups, but many centuries passed before Aristotle's system was replaced.

Linnaeus's system of binomial nomenclature

In the late eighteenth century, a Swedish botanist, Carolus Linnaeus (1707–1778), developed a method of grouping organisms that is still used by scientists today. Linnaeus's system was based on physical and structural similarities of organisms. For example, he might use the similarities in flower parts as a basis for classifying flowering plants, **Figure 17.1**. As a result, the groupings revealed the relationships of the organisms.

Eventually, some biologists proposed that structural similarities reflect the evolutionary relationships of species. For example, although bats fly like birds, they also have hair and produce milk for their young. Therefore, bats are classified as mammals rather than as birds, reflecting the evolutionary history that bats share with other mammals. This way of organizing organisms is the basis of modern classification systems.

Modern classification systems use a two-word naming system called **binomial nomenclature** that Linnaeus developed to identify species. In this system, the first word identifies the genus of the organism. A **genus** (JEE nus) (plural, genera) consists of a group of similar species. The second word, which sometimes describes a characteristic of the organism, is called the **specific epithet**. Thus, the scientific name for each species, referred to as the species name, is a combination of the genus name and specific epithet.

(l)Michael Gadomski/Photo Researchers, (c)Larry Leifer/Grant Heilman Photography, (r)Kenneth Murray/Photo Researchers

Figure 17.1

Linnaeus classified flowering plants according to their flower structures.




For example, the species name of modern humans is *Homo sapiens*. Modern humans are in the genus *Homo*, for example. One of their characteristics is intelligence. The Latin word *sapiens* means “wise.”

Scientific and common names

Latin is the language of scientific names. Taxonomists are required to use Latin because the language is no longer used in conversation and, therefore, does not change. Scientific names should be italicized in print and underlined when handwritten. The first letter of the genus name is uppercase, but the first letter of the specific epithet is lowercase.

Although a scientific name gives information about the relationships of an organism and how it is classified, many organisms have common names just like you and your friends might have nicknames. However, a common name can be misleading. For example, a sea horse is a fish, not a horse. In addition, it is confusing when a species has more than one common name. The bird in **Figure 17.2** lives not only in the United States but also in several countries in Europe. It has a different common name in each country. Therefore, if an English scientist uses the bird’s English common name in an article, a Spanish scientist looking for information might not recognize the bird as the same species.

 **Reading Check** Describe how binomial nomenclature is used to effectively name an organism.

Modern Classification

Expanding on Linnaeus’s work, today’s taxonomists try to identify the underlying evolutionary relationships of organisms and use the information gathered as a basis for classification.



Figure 17.2

In the United States and England, this bird is called the house sparrow; in Spain, the gorrión doméstico; in Holland, the huismus; and in Sweden, the gråsparv. However, the bird has only one scientific name, *Passer domesticus*.

They compare the external and internal structures of organisms, as well as their geographical distribution and genetic makeup to reveal their probable evolutionary relationships. Grouping organisms on the basis of their evolutionary relationships makes it easier to understand biological diversity.

Taxonomy: A framework

Just as similar food items in a supermarket are stacked together, taxonomists group similar organisms, both living and extinct. Classification provides a framework in which to study the relationships among living and extinct species.

For example, biologists study the relationship between birds and dinosaurs within the framework of classification. Are dinosaurs more closely related to birds or to reptiles? The bones of some dinosaurs have large internal spaces like those in birds. In addition, dinosaur skeletons share many other remarkable similarities with birds. Because of such evidence, they suggest that dinosaurs are more closely related to ostriches, which are birds, than to lizards, which are reptiles.

Taxonomy: A useful tool

Classifying organisms can be a useful tool for scientists who work in agriculture, forestry, and medicine.

MiniLab 17.1

Classify

Using a Dichotomous Key in a Field Investigation How could you identify a tree growing in front of your school? You might use a field guide that contains descriptive information or you might use a dichotomous key for trees. A key is made up of sets of numbered statements. Each set deals with a single characteristic of an organism, such as leaf shape or arrangement. Follow the numbered sets until the key reveals the name of the organism.



Procedure

- 1 Collect a few leaves from local trees. Using a dichotomous key for trees of your area, identify the tree from which each leaf came. To use the key, study one leaf. Then choose the statement from the first pair that most accurately describes the leaf. Continue following the key until you identify the leaf's tree. Repeat the process for each leaf.
- 2 Glue each leaf on a separate sheet of paper. For each leaf, record the tree's name.

Analysis

1. **Infer** What is the function of a dichotomous key?
2. **Summarize** List three different characteristics used in your key.
3. **Classify** As you used the key, did the characteristics become more general or more specific?

For example, suppose a child eats berries from a plant in the backyard. The child's parents would probably rush the child and some of the plant and its berries to the nearest hospital. A scientist working at a poison control center could identify the plant, and the physicians would then know how to treat the child.

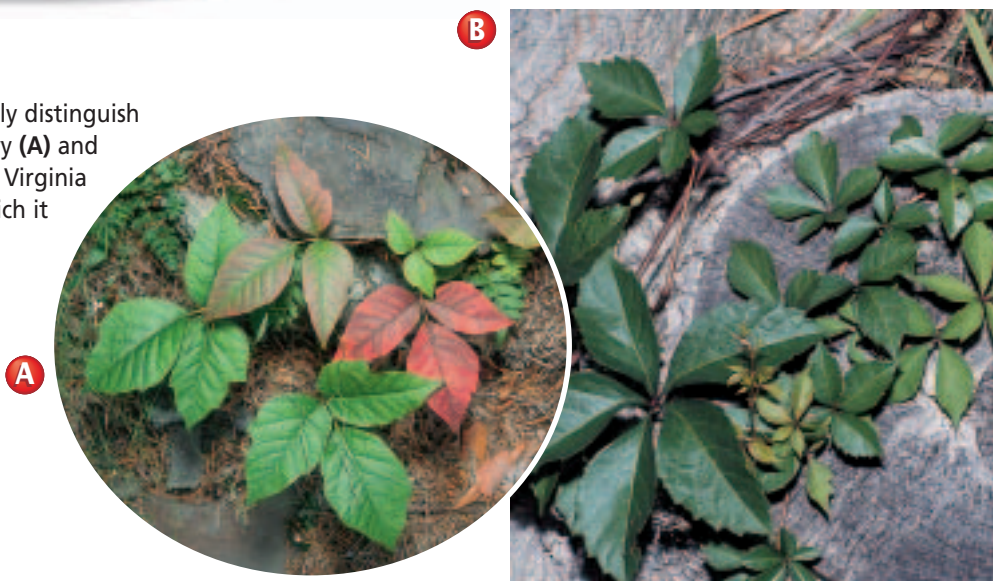
Anyone can learn to identify many organisms, even similar ones such as shown in **Figure 17.3**. The *MiniLab* on this page will guide you through a way of identifying some organisms using a dichotomous key. Then try the *BioLab* at the end of this chapter.

Taxonomy and the economy

It often happens that the discovery of new sources of lumber, medicines, and energy results from the work of taxonomists. The characteristics of a familiar species are frequently similar to those found in a new, related species. For example, if a taxonomist knows that a certain species of pine tree contains chemicals that make good disinfectants, it's possible that another pine species could also contain these useful substances.

Figure 17.3

Taxonomists can easily distinguish among this poison ivy (**A**) and other plants, such as Virginia creeper (**B**), with which it is often confused.



How Living Things Are Classified

In any classification system, items are categorized, making them easier to find and discuss. For example, in a newspaper's classified advertisements, you'll find a section listing autos for sale. This section frequently subdivides the many ads into two smaller groups—domestic autos and imported autos. In turn, these two groups are subdivided by more specific criteria, such as different car manufacturers and the year and model of the auto. Although biologists group organisms, not cars, they subdivide the groups on the basis of more specific criteria. A group of organisms is called a taxon (plural, taxa).

Taxonomic rankings

Organisms are ranked in taxa that range from having very broad characteristics to very specific ones. The broader a taxon, the more general its characteristics, and the more species it contains. You can think of the taxa as fitting together like nested boxes of increasing sizes. You already know about two taxa. The smallest taxon is species. Organisms that look alike and successfully interbreed belong to the same species. The next largest taxon is a genus—a group of similar species that have similar features and are closely related.

It is not always easy to determine the species of an organism. For example, over many years, taxonomists have debated how to classify the red wolf, the coyote, and the gray wolf. Some biologists wanted to classify them as separate species, and others wanted to classify them as a single species. Use the *Problem-Solving Lab* on this page to explore the evidence for and against classifying these three organisms as separate species.

Problem-Solving Lab 17.1

Draw a Conclusion

Is the red wolf a separate species? The work of taxonomists results in changing views of species. This is due to both the discovery of new species and the development of new techniques for studying classification.



Red wolf



Coyote



Gray wolf

Solve the Problem

- 1** The red wolf (*Canis rufus*) can breed and produce offspring with both the coyote (*Canis latrans*) and the gray wolf (*Canis lupus*). Despite this fact, the three animal types have been classified as separate species.
- 2** A biologist measured their skulls and concluded that in size and structure, the red wolf's measurements fell midway between gray wolves and coyotes.
- 3** Based on these data, the biologist concluded that they are separate species.
- 4** Geneticists, attempting to determine if the three animal types were separate species, found that the nucleotide sequences from the red wolf's DNA were not distinctively different from those of gray wolves or coyotes.
- 5** The geneticists concluded that the red wolf is a hybrid of the gray wolf and coyote.

Thinking Critically

- 1. Infer** A species can be defined as a group of animals that can mate with one another to produce fertile offspring but cannot mate successfully with members of a different group. Does statement (1) support or reject this definition? Explain.
- 2. Infer** What type of evidence was the biologist using in (2)? The geneticists in (4)? Explain.
- 3. Interpret** A hybrid is the offspring from two species. Which sentence, besides (4) and (5), supports hybrid evidence? Explain.
- 4. Analyze** If you supported the biologist's work, would you use the three different scientific names for coyotes, gray wolves, and red wolves? Explain.
- 5. Analyze** If you supported the geneticists' conclusions, would you use the three different scientific names? Explain.
- 6. Infer** Analyze the relationships among the red wolf, coyote, and gray wolf according to physical and genetic factors.

CAREERS IN BIOLOGY

Biology Teacher

Are you intrigued by the actions and interactions of plants, animals, and other organisms? Would you like to share this interest with others? Maybe you should become a biology teacher.

Skills for the Job

Biology teachers help students learn about organisms through discussions and activities both inside and outside the classroom. As a biology teacher, you might also teach general science and health. To become a biology teacher, you must earn a bachelor's degree in science, biology, or a closely related field. You sometimes have to spend several months student teaching. Many positions require a master's degree. In many states, you have to pass a national test for teachers. This national test includes a test in biology or in a combination of biology and general science. After all this education, testing, and work, you will be ready to teach others!



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In *Figure 17.4*, you can compare the appearance of a lynx, *Lynx canadensis*, a bobcat, *Lynx rufus*, and a mountain lion, *Felis concolor*. The scientific names of the lynx and bobcat tell you that they belong to the same genus, *Lynx*. All species in the genus *Lynx* share the characteristic of having a jaw that contains 28 teeth. Mountain lions and other lions, which are similar to bobcats and lynxes, are not classified in the *Lynx* genus because their jaws contain 30 teeth.

Bobcats, lynxes, lions, and mountain lions belong to the same family called Felidae. **Family**, the next larger taxon in the biological classification system, consists of a group of similar genera. In addition to domesticated cats, bobcats, lynxes, and lions belong to the family Felidae. All members of the cat family share certain characteristics. They have short faces, small ears, forelimbs with five toes, and hindlimbs with four toes. Most can retract their claws.

Figure 17.4

Mountain lions (A) are not classified in the same genus as lynxes (B) and bobcats (C).



A

B



C



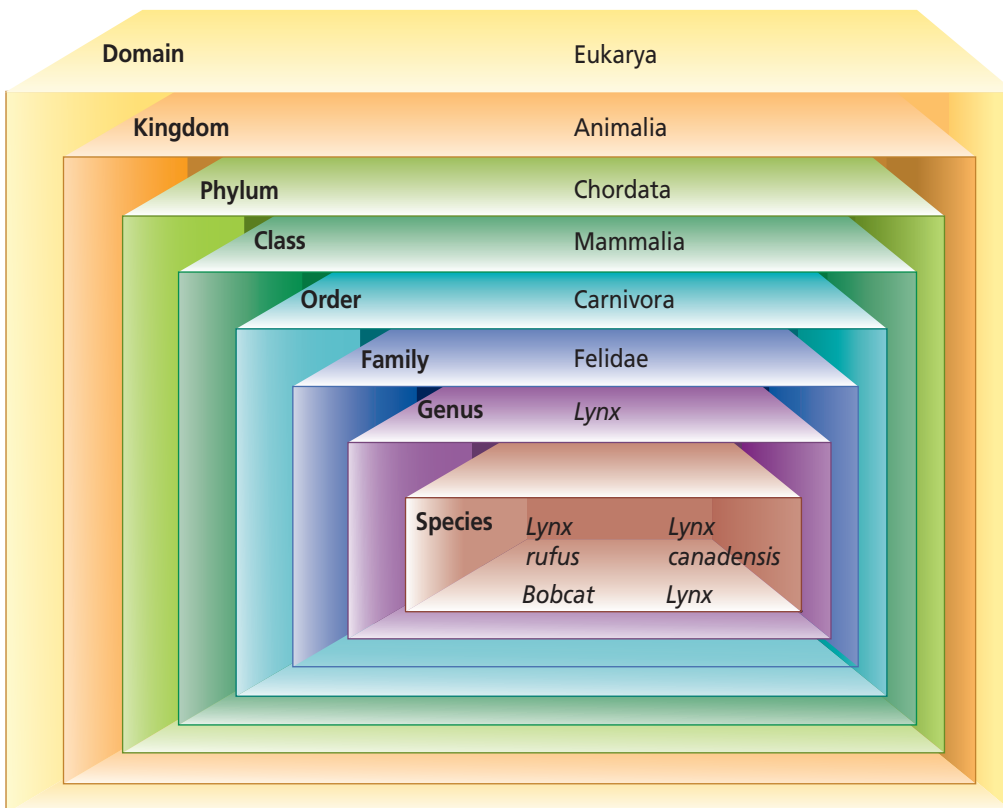


Figure 17.5
Although the lynx and bobcat are different species, they belong to the same genus, family, order, class, phylum, and kingdom. **Observe and Infer** *What class do the bobcat and lynx belong to? What kingdom do both belong to?*

The larger taxa

There are five larger taxa following family. An **order** is a taxon of similar families. A **class** is a taxon of similar orders. A **phylum** (FI lum) (plural, phyla) is a taxon of similar classes. Plant taxonomists use the taxon **division** instead of phylum. A **kingdom** is a taxon of similar phyla or divisions. A domain contains one or more kingdoms. The six kingdoms are described in the next section.

The bobcat and lynx that were compared earlier are both classified completely in **Figure 17.5**. Although the six-kingdom classification system primarily is used in this textbook, several other classification systems exist. Recently, many taxonomists began including a fifth taxa called domains, which include all six kingdoms. You can learn more about domains and other classification systems on pages 1070–1073 in the *Focus On*.

Section Assessment

Understanding Main Ideas

- For what reasons are biological classification systems needed?
- Give two reasons why binomial nomenclature is useful.
- Describe what Linnaeus contributed to the field of taxonomy.
- What are the taxa used in biological classification? Which taxon contains the largest number of species? Which taxon contains the fewest number of species?

Thinking Critically

- Use categories that parallel the taxa of a biological classification system to organize the items you can borrow from a library.

SKILL REVIEW

- Classify** Using taxonomic nomenclature, organize the furniture in your home based on function. Develop a model of a hierarchical classification system based on similarities and differences. For more help, refer to *Classify* in the **Skill Handbook**.



Section 17.2

SECTION PREVIEW

Objectives

Describe how evolutionary relationships are determined.

Explain how cladistics reveals phylogenetic relationships.

Compare the six kingdoms of organisms.

Review Vocabulary

archaeobacteria: chemosynthetic prokaryotes that live in harsh environments (p. 384)

New Vocabulary

phylogeny
cladistics
cladogram
eubacteria
protist
fungus

The Six Kingdoms

Family Features

Using an Analogy Suppose you entered a room full of strangers and were asked to identify two related people. What clues would you look for? You might listen to hear similar-sounding voices. You might look for similar hair, eye, and skin coloration. You might watch for shared behaviors and mannerisms between individuals. When taxonomists want to identify evolutionary relationships among species, they examine the characteristics of each species.

Compare and Contrast *What physical characteristics do you share with your parents? What physical characteristics make you different from them?*



The Western sword fern (*Polystichum munitum*) and Northern holly fern (*Polystichum lonchitis*) (inset) have a similar structure.

How are evolutionary relationships determined?

Evolutionary relationships are determined on the basis of similarities in structure, breeding behavior, geographical distribution, chromosomes, and biochemistry. Because these characteristics provide the clues about how species evolved, they also reveal the probable evolutionary relationships of species.

Structural similarities

Structural similarities among species reveal relationships. For example, the presence of many shared physical structures implies that species are closely related and may have evolved from a common ancestor. For example, because lynxes and bobcats have structures more similar to each other than to members of any other groups, taxonomists suggest that they share a common ancestor. Likewise, plant taxonomists use structural evidence to classify dandelions and sunflowers in the same family, Asteraceae, because they have similar flower and fruit structures.

A**B****Figure 17.6**

DNA sequences in red pandas (A) and giant pandas (B) suggest that red pandas are more closely related to raccoons, and giant pandas are more closely related to bears.

If you observe an unidentified animal that can retract its claws, you can infer that it belongs to the cat family. You can then assume that the animal has other characteristics in common with cats. Taxonomists observe and compare features among members of different taxa and use this information to infer their evolutionary history.

Breeding behavior

Sometimes, breeding behavior provides important clues to relationships among species. For example, two species of frogs, *Hyla versicolor* and *Hyla chrysoscelis*, live in the same area and look similar. During the breeding season, however, there is an obvious difference in their mating behavior. The males of each species make different sounds to attract females, and therefore attract and mate only with members of their own group. Scientists concluded that the frogs were two separate species.

Geographical distribution

The location of species on Earth helps biologists determine their relationships with other species. For example, many different species of finches live on the Galápagos Islands off the coast of South America. Biologists propose that in the past some members of a finchlike bird species that lived in South America reached the Galápagos Islands, where they became isolated. These finches probably spread into different niches on the volcanic islands and evolved over time into many

distinct species. The fact that they share a common ancestry is supported by their geographical distribution in addition to their genetic similarities.

Chromosome comparisons

Both the number and structure of chromosomes, as seen during mitosis and meiosis, provide evidence about relationships among species. For example, cauliflower, cabbage, kale, and broccoli look different but have chromosomes that are almost identical in structure. Therefore, biologists propose that these plants are related. Likewise, the similar appearance of chromosomes among chimpanzees, gorillas, and humans suggests a common ancestry.

Biochemistry

Powerful evidence about relationships among species comes from biochemical analyses of organisms. Closely related species have similar DNA sequences and, therefore, similar proteins. In general, the more inherited nucleotide sequences that two species share, the more closely related they are. For example, the DNA sequences in giant pandas and red pandas differ. They differ so much that many scientists suggest that giant pandas are more closely related to bears than to red pandas, such as the one shown in **Figure 17.6**. Read the *Biotechnology* feature at the end of this chapter to learn more about how chemical similarities can reveal evolutionary relationships.

Phylogenetic Classification: Models

Word Origin

phylogeny from the Greek words *phylon*, meaning "related group," and *geny*, meaning "origin"; Organisms are classified based on their phylogeny.

cladistics from the Greek word *klados*, meaning "sprout" or "branch"; Cladistics is based on phylogeny.

Species that share a common ancestor also share an evolutionary history. The evolutionary history of a species is called its **phylogeny** (fy LAH juh nee). A classification system that shows the evolutionary history of species is a phylogenetic classification and reveals the evolutionary relationships of species.

Early classification systems did not reflect the phylogenetic relationships among organisms. As scientists learned more about evolutionary relationships, they modified the early classification schemes to reflect the phylogeny of species.

Cladistics

One biological system of classification that is based on phylogeny is **cladistics** (kla DIHS tiks). Scientists who use cladistics assume that as groups of organisms diverge and evolve from a common ancestral group, they retain some unique inherited characteristics that taxonomists call derived traits. Biologists identify a group's derived traits and use them to make a branching diagram called a

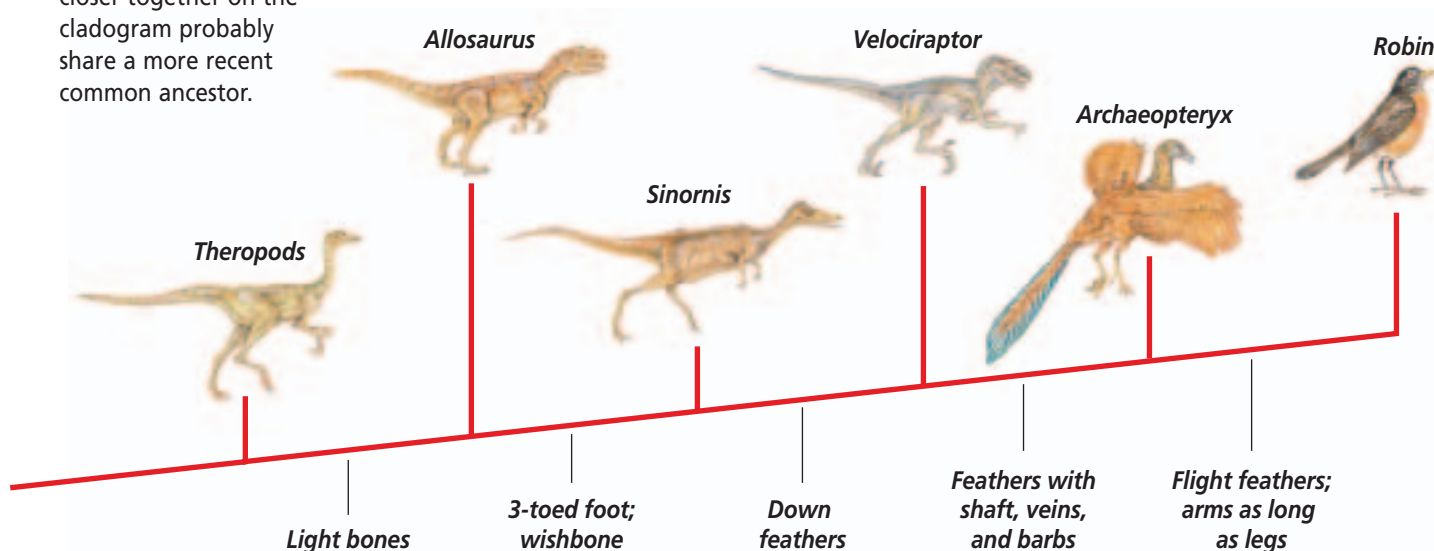
cladogram (KLA deh gram). A cladogram is a model of the phylogeny of a species, and models are important tools for understanding scientific concepts.

Cladograms are similar to the pedigrees, or family trees, you studied in an earlier chapter. Branches on both pedigrees and cladograms show proposed ancestry. In a cladogram, two groups on diverging branches probably share a more recent ancestor than those groups farther away. If two organisms are near each other on a pedigree's branch, they also share an ancestor. However, an important difference between cladograms and pedigrees is that, whereas pedigrees show the direct ancestry of an organism from two parents, cladograms show a probable evolution of a group of organisms from ancestral groups.

In **Figure 17.7**, you see the cladogram for modern birds, such as robins. How was the cladogram developed? First, taxonomists identified the derived traits of modern birds—flight feathers, light bones, a wishbone, down feathers, and feathers with shafts. Next, they identified ancestral species that have at least

Figure 17.7

This cladogram uses the derived traits of a modern bird, such as the robin, to model its phylogeny. Groups that are closer together on the cladogram probably share a more recent common ancestor.



some of these traits. Most biologists agree that the ancestors of birds are a group of dinosaurs called theropods. Some of these theropods are *Allosaurus*, *Archaeopteryx*, *Velociraptor*, *Sinornis*, and *Protarchaeopteryx*. Each of these ancestors has a different number of derived traits. Some groups share more derived traits than others.

Finally, taxonomists constructed the robin's cladogram from this information. They assume that if groups share many derived traits, they share common ancestry. Thus, *Archaeopteryx* and the robin, which share four derived traits, are on adjacent branches, indicating a recent common ancestor. Use the *MiniLab* on this page to construct a cladogram for another species.

Another type of model

In this book, you will see cladograms and other types of models that provide information about the phylogenetic relationships among species. One type of model resembles a fan. Unlike a cladogram, a fanlike model may communicate the time organisms became extinct or the relative number of species in a group. A fanlike diagram incorporates fossil information and the knowledge gained from anatomical, embryological, genetic, and cladistic studies.

In *Figure 17.8* on the next page, you can see a fanlike model of the six-kingdom classification system. This model includes both Earth's geologic time scale and the probable evolution of organisms during that time span. In addition, this fanlike diagram helps you to find relationships between modern and extinct species.

Groups of organisms that are closer in the same colored ray share more inherited characteristics.

MiniLab 17.2

Classify

Using a Cladogram to Show Relationships Cladograms were developed by Willi Hennig. They use derived characteristics to illustrate evolutionary relationships.

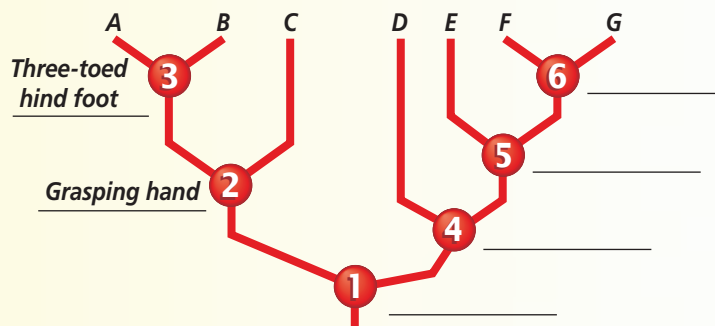
Procedure

- The following table shows the presence or absence of six derived traits in the seven dinosaurs that are labeled A–G.
- Use the information listed in the table below to answer the following questions.

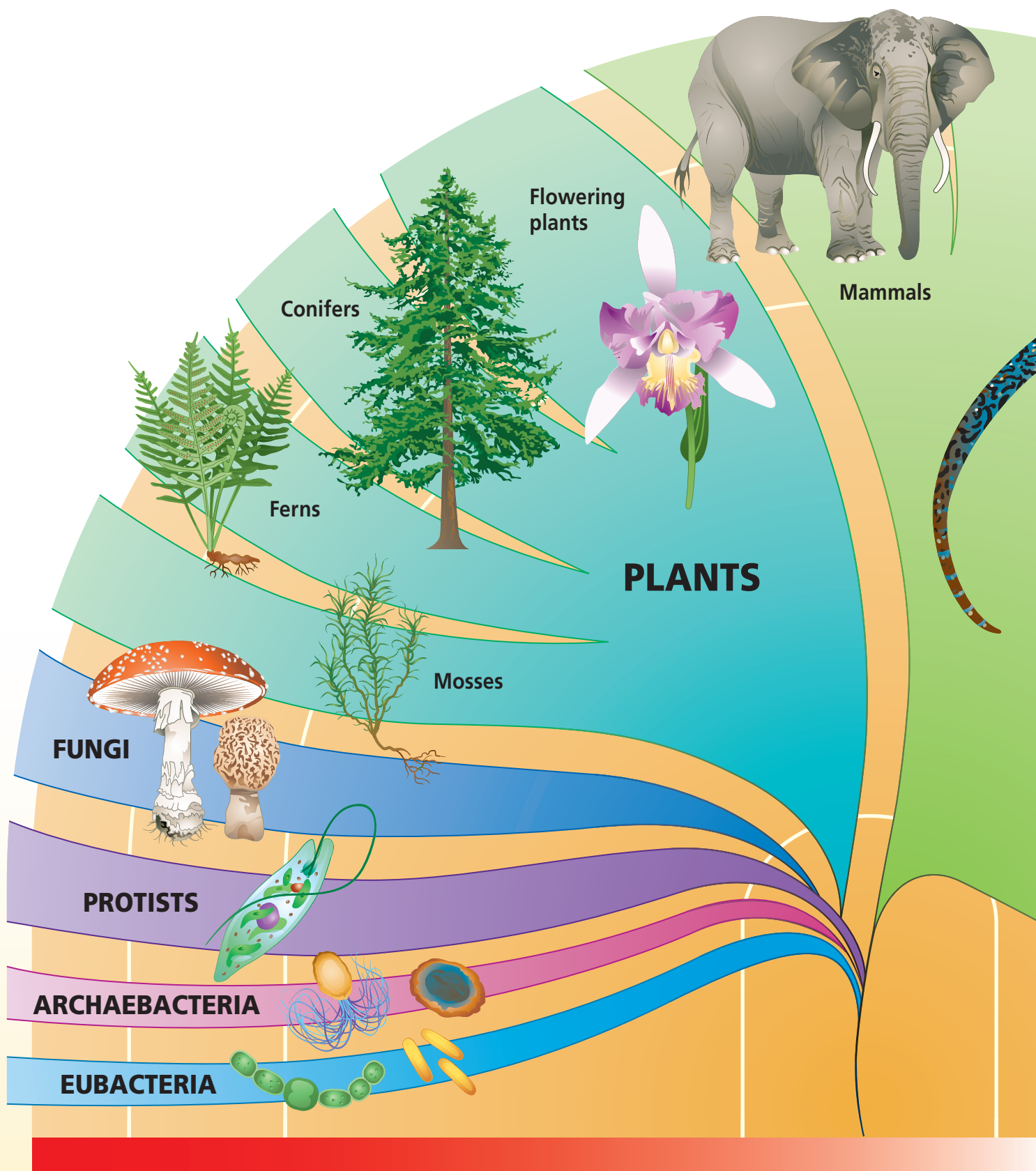
Derived Traits of Dinosaurs							
Dinosaur Trait	A	B	C	D	E	F	G
Hole in hip socket	yes	yes	yes	yes	yes	yes	yes
Extension of pubis bone	no	no	no	yes	yes	yes	yes
Unequal enamel on teeth	no	no	no	no	yes	yes	yes
Skull has "shelf" in back	no	no	no	no	no	yes	yes
Grasping hand	yes	yes	yes	no	no	no	no
Three-toed hind foot	yes	yes	no	no	no	no	no

Analysis

- Classify** Copy the partially completed cladogram. Complete the missing information on the right side.



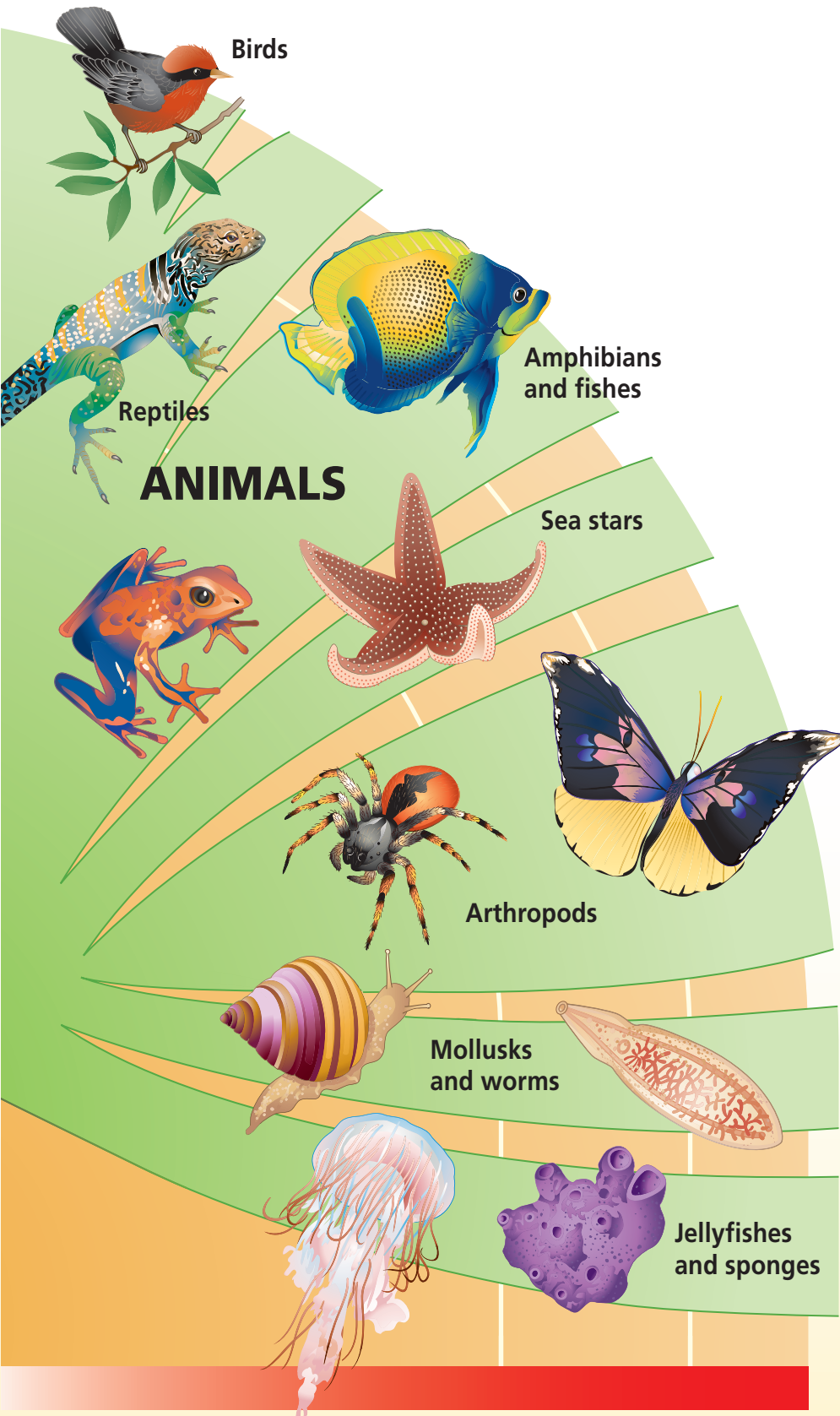
- Observe** How many traits does dinosaur F share with dinosaur C, with dinosaur D, and with dinosaur E?
- Infer** Dinosaurs A and B form a grouping called a clade. The dinosaurs A, B, and C form another clade. What derived trait is shared only by the A and B clade? By the A, B, and C clade? By the D, E, F, and G clade?
- Infer** Traits that evolved very early, such as the hole in the hip socket, are called primitive traits. The traits that evolved later, such as a grasping hand, are called derived traits. Are primitive traits typical of broader or smaller clades? Are derived traits typical of broader or smaller clades? Give an example in each case.



Life's Six Kingdoms

Figure 17.8

In this phylogenetic diagram, six colors represent the six kingdoms of living things. The phylogeny of organisms is represented by a fanlike structure perched on the geologic time scale. The fan's base represents the origin of life during the Precambrian. The fan's rays represent the probable evolution of species from the common origin. The major groups of modern organisms occupy the fan's outer edge, which represents present time. **Critical Thinking** *Identify characteristics of each of the six kingdoms.*

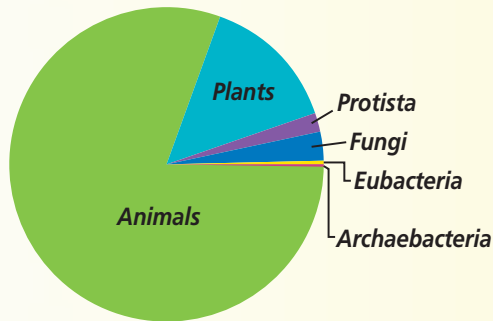


Problem-Solving Lab 17.2

Use Graphs

How many species are there in each kingdom? You may not realize it, but you probably already have seen more than 1000 different species since you were born.

How close might you be to having seen all the known different species that exist?



Solve the Problem

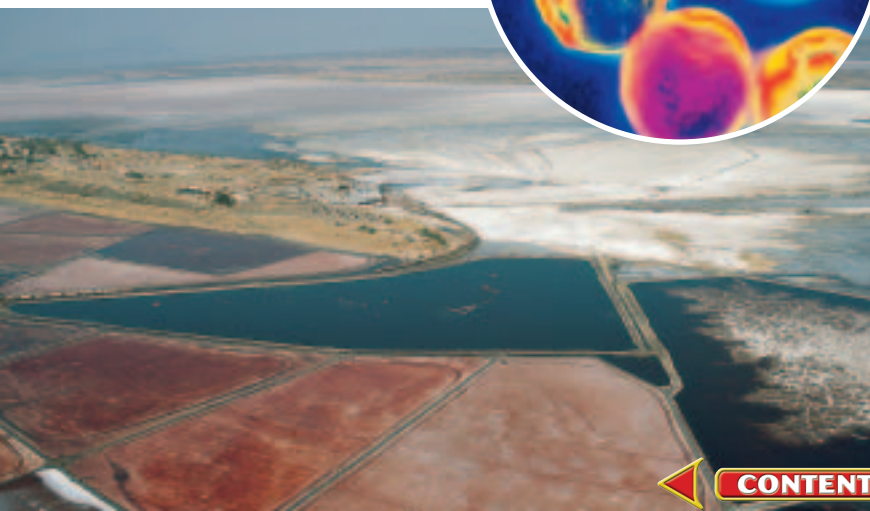
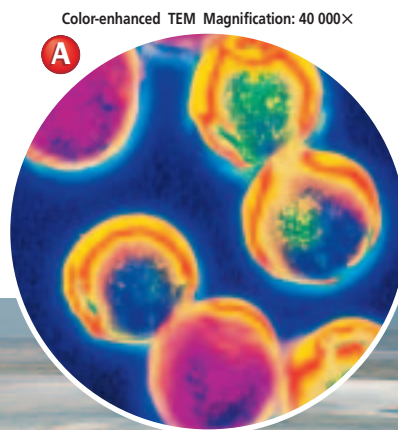
The circle graph above shows Earth's six kingdoms. List the approximate number of species for each of the six kingdoms. Each degree of the circle graph is equal to 10 000 species. Archaeobacteria represent $\frac{1}{20}$ of a degree, and Eubacteria represent 1 degree.

Thinking Critically

- Analyze** What is the approximate total number of species for all life-forms on Earth?
- Analyze** What approximate percent of the total life-forms on Earth are in each kingdom?
- Analyze** Why do the above questions refer to the number of species as "approximate"?

Figure 17.9

Most archaeobacteria, such as these salt-loving *Halococcus* (A) live in extreme environments, such as seawater evaporating ponds (B).



They are probably more closely related than groups that are farther apart. For example, find the jellyfishes, the fishes, and the reptiles on the model. Notice that fishes and reptiles are closer to each other than they are to the jellyfishes, indicating that they are more closely related to each other than they are to jellyfishes.

✓ Reading Check Evaluate the two models of classification and their adequacy in representing biological events.

The Six Kingdoms of Organisms

As you saw in *Figure 17.8*, the six kingdoms of organisms are archaeobacteria, eubacteria, protists, fungi, plants, and animals. In general, differences in cellular structures and methods of obtaining energy are the two main characteristics that distinguish among the members of the six kingdoms. Learn more about the number of species in each kingdom in the *Problem-Solving Lab* on this page.

Prokaryotes

The prokaryotes, organisms with cells that lack distinct nuclei bounded by a membrane, are microscopic and unicellular. Some are heterotrophs and some are autotrophs. In turn, some prokaryotic autotrophs are chemosynthetic, whereas others are photosynthetic. There are two kingdoms of prokaryotic organisms: Archaeobacteria and Eubacteria. The oldest prokaryotic fossils are about 3.5 billion years old.

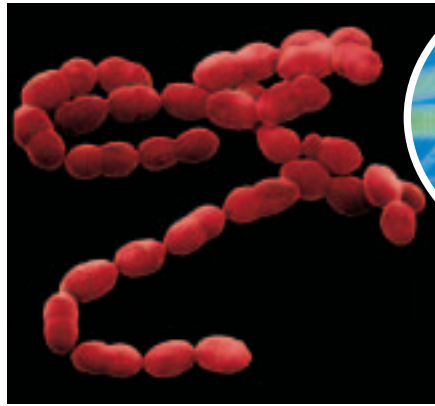
There are several hundred species of known archaeobacteria and most of them live in extreme environments such as swamps, deep-ocean hydrothermal vents, and seawater evaporating ponds, like the one in *Figure 17.9*.

(b)Gregory G. Dimijian, M.D./Photo Researchers, (inset)Alfred Pasieka/Science Photo Library/Photo Researchers

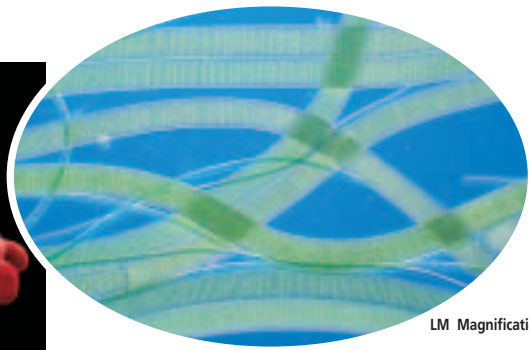
Figure 17.10

Eubacteria are a diverse kingdom of prokaryotes. Both their cellular structure and the way they obtain food vary widely.

A The bacteria that cause strep throat are heterotrophs called *Streptococcus*.



Magnification: 40 000×



LM Magnification: 100×

B Cyanobacteria, such as *Oscillatoria*, live in freshwater and are photosynthetic.

Most of these environments are oxygen-free. The lipids in the cell membranes of archaeobacteria, the composition of their cell walls, and the sequence of nucleic acids in their ribosomal RNA differ considerably from those of other prokaryotes. In addition, their genes have a similar structure to those in eukaryotes.

All of the other prokaryotes, about 5000 species of bacteria, are classified in Kingdom Eubacteria. **Eubacteria**, such as those shown in *Figure 17.10*, have very strong cell walls and a

less complex genetic makeup than found in archaeobacteria or eukaryotes. They live in most habitats except the extreme ones inhabited by the archaeobacteria. Although some eubacteria cause diseases, such as strep throat and pneumonia, most bacteria are harmless and many are actually helpful.

Protists: A diverse group

Kingdom Protista contains diverse species, as shown in *Figure 17.11*, that share some characteristics.

Figure 17.11

Although these three protists look different, they are all eukaryotes and live in moist environments.



A Funguslike slime molds often live in damp forests, feeding on microorganisms.



Magnification: 150×

B The paramecium is an animal-like protist that moves through water.



C These kelps are multicellular plantlike protists. Although they look like plants, they do not have organs or organ systems.

Figure 17.12

Morels are edible fungi that grow for only a few days in only a few places. Identify **What are the characteristics of the fungi kingdom?**



A **protist** is a eukaryote that lacks complex organ systems and lives in moist environments. Fossils of plant-like protists show that protists existed on Earth up to two billion years ago. Although some protists are unicellular, others are multicellular. Some are plantlike autotrophs, some are animal-like heterotrophs, and others are funguslike heterotrophs that produce reproductive structures like those of fungi.

Fungi: Earth's decomposers

Organisms in Kingdom Fungi are heterotrophs that do not move from place to place. A **fungus** is either a unicellular or multicellular eukaryote that absorbs nutrients from organic materials in the environment. Fungi first appeared in the fossil record over 400 million years ago. There are more than 50 000 known species of fungi, including the one you see in **Figure 17.12**.

Plants: Multicellular oxygen producers

All of the organisms in Kingdom Plantae are multicellular, photosynthetic eukaryotes. None moves from place to place. A plant's cells usually contain chloroplasts and have cell walls composed of cellulose. Plant cells are organized into tissues that, in turn, are organized into organs and organ systems. You can see two of the many diverse types of plants in **Figure 17.13**.

The oldest plant fossils are more than 400 million years old.

Figure 17.13

A *Hibiscus* is just one kind of flowering plant (**A**). Tropical tree ferns do not produce flowers (**B**).



B



Figure 17.14

Many animals have well-developed nervous and muscular systems.

A The luna moth's antennae are sense organs, which are part of its nervous system. The moth's antennae detect tiny quantities of chemicals in the air.



B The cheetah uses many of its organ systems, especially its nervous and muscular systems, to speed through the grasslands, perhaps chasing prey.

However, some scientists propose that plants existed on Earth's land-masses much earlier than these fossils indicate. Plants do not fossilize as often as organisms that contain hard structures, such as bones, which more readily fossilize than soft tissues.

There are more than 250 000 known species of plants. Although you may be most familiar with flowering plants, there are many other types of plants, including mosses, ferns, and evergreens.

Animals: Multicellular consumers

Animals are multicellular heterotrophs. Nearly all are able to move from place to place. Animal cells do not have cell walls. Their cells are organized into tissues that, in turn, are organized into organs and complex organ systems. Some organ systems in animals are the nervous, circulatory, and muscular systems, *Figure 17.14*. Animals first appeared in the fossil record about 600 million years ago.

Section Assessment

Understanding Main Ideas

1. How do members of the different kingdoms obtain nutrients?
2. Make a list of the characteristics that archaeobacteria and eubacteria share. Then make a list of their differences.
3. What does it mean for species to have an evolutionary relationship? Identify five ways these relationships are determined. Describe each briefly and give an example for each.
4. How do cladograms and fanlike diagrams differ?

Thinking Critically

5. Why is phylogenetic classification more natural than a system based on characteristics such as medical usefulness, or the shapes, sizes, and colors of body structures?

Skill Review

6. **Make and Use Tables** Make a table that compares the characteristics of members of each of the six kingdoms. For more help, refer to *Make and Use Tables* in the **Skill Handbook**.



bdol.glencoe.com/self_check_quiz

INVESTIGATE BioLab

Before You Begin

Do you remember the first time you saw a beetle? You may have asked someone nearby, "What is it?" You may still be curious to know the names of insects you see. To help identify organisms, taxonomists have developed dichotomous keys. A dichotomous key is a set of paired statements that can be used to identify organisms. When you use a dichotomous key, you choose one statement from each pair that best describes the organism. At the end of each statement you chose, you are directed to the next set of statements to use. Finally, you will reach the name of the organism or the group to which it belongs.



Long-horned,
wood-boring
beetle

Making a Dichotomous Key

PREPARATION

Problem

How is a dichotomous key made?

Objectives

In this BioLab, you will:

- **Classify** organisms on the basis of structural characteristics.
- **Develop** a dichotomous key.

Materials

sample keys from guidebooks
metric ruler



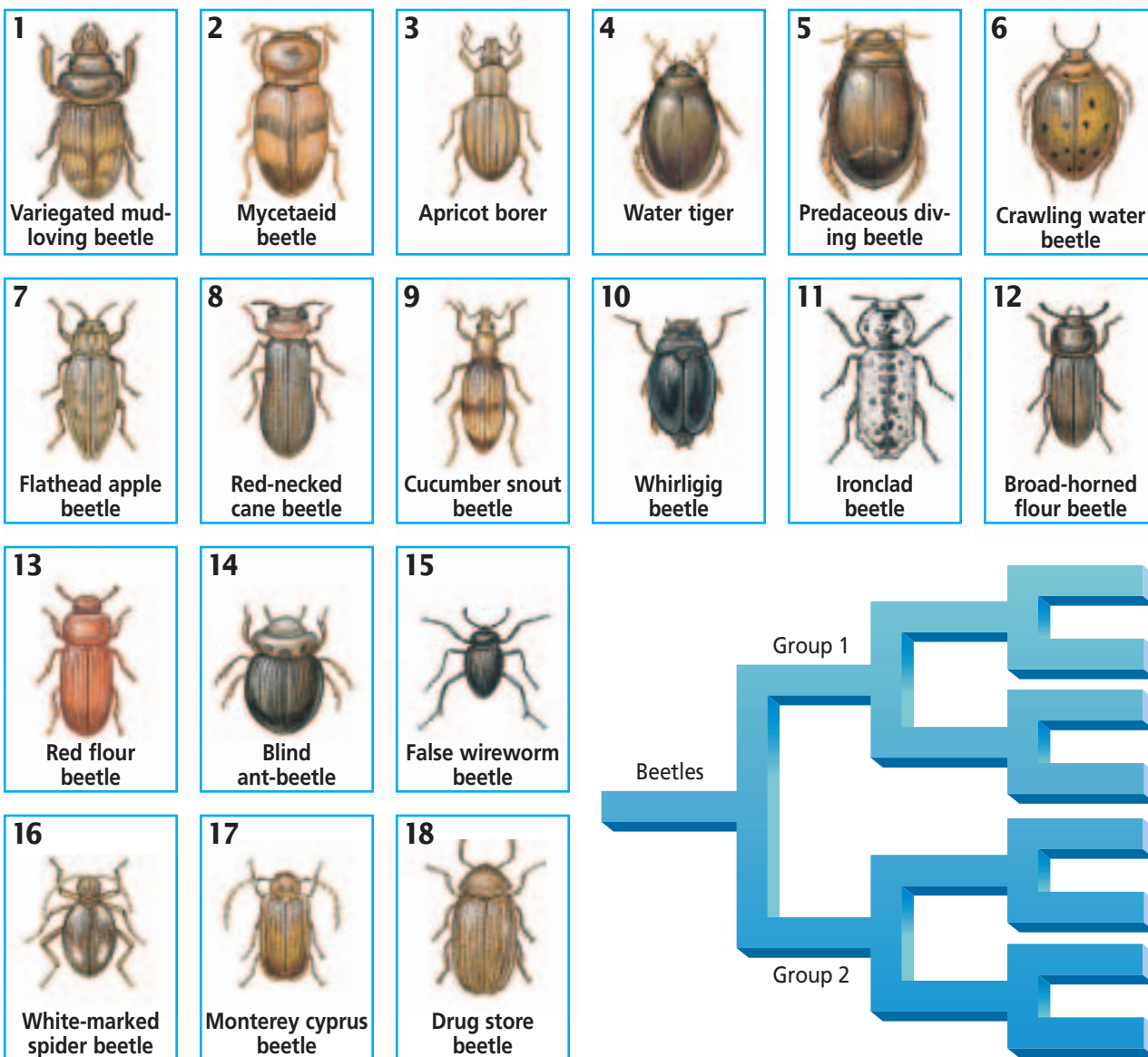
Scarab beetle

Skill Handbook

If you need help with this lab, refer to the **Skill Handbook**.

PROCEDURE

1. Study the numbered drawings of beetles.
2. Choose one characteristic of the beetles, and classify the beetles into two groups based on that characteristic. Take measurements if you wish.
3. Record the chosen characteristic in a diagram like the one shown. Write the numbers of the beetles in each group on your diagram.
4. Continue to form subgroups within your two groups based on different characteristics. Record the characteristics and numbers of the beetles in your diagram until you have only one beetle in each group.
5. Using the diagram you have just made, make a dichotomous key for the beetles. Remember that each numbered step should contain two choices for classification. Begin with 1A and 1B. For help, examine sample keys provided by your teacher.
6. Exchange dichotomous keys with another team. Use their key to identify the beetles.



ANALYZE AND CONCLUDE

- 1. ERROR ANALYSIS** Was the dichotomous key you constructed exactly like those of other students? Why might they be different?
- 2. Analyze Data** What characteristics were most useful for making a classification key for beetles? What characteristics were not useful?
- 3. Think Critically** Why do keys typically offer only two choices and not more?

Apply Your Skill

Application Using the same procedure that you just used to make a beetle key, make a dichotomous key to identify the students in your class.



Web Links To find out more about identifying organisms, visit bdol.glencoe.com/dichotomous_key

Molecular Clocks

How long ago did animals first appear on Earth? Did the giant panda evolve along the same family line as bears or raccoons? To help answer questions like these, biologists have learned how to use DNA, proteins, and other biological molecules as “clocks” that reveal details about evolutionary relationships.

Accumulated molecular differences in the DNA of two species can indicate how long they have been separate species. Comparing both the DNA base sequences and the amino acid sequence of a specific protein of two species can indicate the closeness of their relationship.

Comparing DNA One way to compare DNA is to measure how strongly the single strands of DNA from two species will bond. This method is known as DNA-DNA hybridization. Double-stranded DNA from each species is heated to separate the complementary strands. Then the single strands of DNA from each species are mixed and allowed to cool. As the DNA cools, the single strands from the two species bond, or hybridize. If the species are closely related, more of their DNA base pairs will match, and their DNA strands will bond strongly.

Another method of comparing the DNA of species is called DNA sequencing. Biologists select a gene that species have in common and compare the genes’ bases. Counting how many base pairs differ can indicate approximately how long ago each species became distinct. Estimates obtained by DNA sequencing show that many of the animal phyla began to appear on Earth about 1.2 billion years ago.

Protein clocks A specific protein is assumed to evolve at about the same rate in all species that contain the protein. Comparing the amino acid sequences of the protein in several species can show about how long ago the species diverged. For example, cytochrome *c* is a protein in the



Flamingoes and storks are closely related.



cells of aerobic organisms. Both human and chimpanzee cytochrome *c* have the same amino acid sequence. The cytochrome *c* of other primates has a different amino acid sequence.

Applications DNA-DNA hybridization has shown that flamingoes are more closely related to storks than they are to geese. Protein clock data suggest that humans and chimpanzees became distinct species recently in the history of Earth. These biotechnological methods are useful in determining phylogenetic relationships.

Applying Biotechnology

Analyze Information The cytochrome *c* found in humans and chimpanzees differs from that found in dogs by 13 amino acids, in tuna by 31 amino acids, and in rattlesnakes by 20 amino acids. What assumptions can you make based on this information?



To find out more about molecular clocks, visit bdol.glencoe.com/biotechnology

Chapter 17 Assessment

STUDY GUIDE

Section 17.1

Classification



Key Concepts

- Although Aristotle developed the first classification system, Linnaeus laid the foundation for modern classification systems by using structural similarities to organize species and by developing a binomial naming system for species.
- Scientists use a two-word system called binomial nomenclature to give species scientific names.
- Classification provides an orderly framework in which to study the relationships among living and extinct species.
- Organisms are classified in a hierarchy of taxa: domain, kingdom, phylum or division, class, order, family, genus, and species.

Vocabulary

binomial nomenclature (p. 444)
class (p. 449)
classification (p. 443)
division (p. 449)
family (p. 448)
genus (p. 444)
kingdom (p. 449)
order (p. 449)
phylum (p. 449)
specific epithet (p. 444)
taxonomy (p. 443)

Section 17.2

The Six Kingdoms



Key Concepts

- Biologists use similarities in body structures, breeding behavior, geographic distribution, chromosomes, and biochemistry to determine evolutionary relationships.
- Modern classification systems are based on phylogeny—the evolutionary history of a species.
- Kingdoms Archaeobacteria and Eubacteria contain only unicellular prokaryotes.
- Kingdom Protista contains eukaryotes that lack complex organ systems.
- Kingdom Fungi includes heterotrophic eukaryotes that absorb their nutrients.
- Kingdom Plantae includes multicellular eukaryotes that are photosynthetic.
- Kingdom Animalia includes multicellular, eukaryotic heterotrophs with cells that lack cell walls.

Vocabulary

cladistics (p. 452)
cladogram (p. 452)
eubacteria (p. 457)
fungus (p. 458)
phylogeny (p. 452)
protist (p. 458)



Magnification: 150×



To help you review the organization of life's diversity, use the Organizational Study Fold on page 443.



Chapter 17 Assessment

Vocabulary Review

Review the Chapter 17 vocabulary words listed in the Study Guide on page 463. Match the words with the definitions below.

1. modern classification system using a two-word name
2. large taxon that contains similar classes
3. biological system of classification based on phylogeny
4. branch of biology that groups and names organisms based on their characteristics
5. branching diagram showing derived traits

Understanding Key Concepts

6. Which taxon contains the others?
A. family
B. species
C. order
D. phylum
7. Unlike a pedigree, a cladogram _____.
A. shows ancestry
B. shows hypothesized phylogeny
C. indicates ancestry from two parents
D. explains relationships
8. Which of the following pairs of terms are most closely related?
A. Linnaeus—DNA analysis
B. Aristotle—binomial nomenclature
C. protist—prokaryote
D. taxonomy—classification
9. Linnaeus based most of his classification system on _____.
A. cell organelles
B. biochemical comparisons
C. structural comparisons
D. embryology
10. A group of prokaryotes that often live in extreme environments is the _____.
A. archaeobacteria
B. protists
C. eubacteria
D. fungi

11. Which of the following describes the organism shown to the right?
A. unicellular consumer
B. unicellular producer
C. multicellular consumer
D. multicellular producer

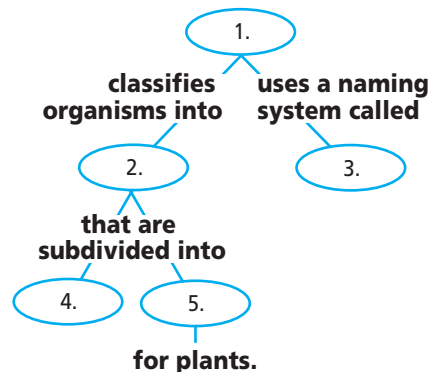


Constructed Response

12. **Open Ended** Explain why Linnaeus's system of classification is more useful than Aristotle's.
13. **Open Ended** Explain why classification systems continue to be updated with newer versions. What improvements and problems do such updates cause?
14. **Open Ended** You find an unusual organism growing on the bark of a dying tree. Under a microscope, you observe that its cells are eukaryotic, have cell walls, and do not contain chloroplasts. Into what kingdom would you classify this organism? Explain your decision.

Thinking Critically

15. **Compare and Contrast** Compare the classification system of your school library with that of organisms.
16. **Concept Map** Complete the concept map by using the following vocabulary terms: divisions, taxonomy, kingdoms, binomial nomenclature, phyla.



Chapter 17 Assessment

17. **REAL WORLD BIOCHALLENGE** Classification is a system that is both rich and orderly. It lends itself to the Internet. Visit bdol.glencoe.com to find out about the classification of a taxon of your

choice. What are the major taxa within the one you chose? Create a poster or other illustration displaying a cladogram of your findings. Present your illustration to the class. Explain the characteristics at the nodes.

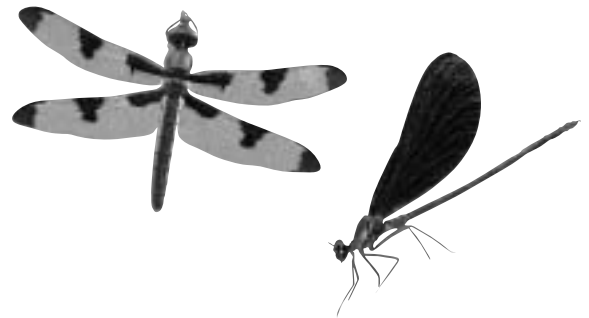
Standardized Test Practice

Part 1 Multiple Choice

Use the table below to answer questions 18–20.

Classification of Representative Mammals			
Kingdom	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Mammalia
Order	Cetacea	Carnivora	Carnivora
Family	Mysticeti	Mustelidae	Felidae
Genus	<i>Balenopora</i>	<i>Mustela</i>	<i>Felis</i>
Species	<i>B. physalus</i>	<i>M. furo</i>	<i>F. catus</i>
Common Name	Blue Whale	Ferret	Domestic cat

18. Which animal is least related to the others?
A. domestic cat **C.** ferret
B. blue whale **D.** all equally related
19. At which level does the ferret diverge from the blue whale?
A. species **C.** family
B. genus **D.** order
20. At which level does the ferret diverge from the domestic cat?
A. species **C.** family
B. genus **D.** order
21. Which of the following is not a species?
A. *H. sapiens* **C.** bluebird
B. *Quercus alba* **D.** *M. polyglottis*



Key

1A	Front and hind wings similar in size and shape, and folded parallel to the body when at rest damselflies
1B	Hind wings wider than front wings near base, and extended on either side of the body when at rest dragonflies

Study the dichotomous key and answer questions 22 and 23.

22. The insect on the right is a damselfly because it has _____.
A. wings that are opaque
B. wings folded at rest
C. smaller eyes
D. wings not similar in size
23. The insect on the left is a dragonfly because it has _____.
A. wings that are opaque
B. wings folded at rest
C. larger eyes
D. wings not similar in size

Part 2 Open Ended/Grid In

Record your answers on your answer document.

24. **Open Ended** From the key and the photographs above, identify traits that indicate dragonflies and damselflies may have evolved from a common ancestor.
25. **Open Ended** What does a dichotomous key tell about an organism? What kinds of information does it not give?



BioDigest UNIT 5 REVIEW

Change Through Time

Scientists propose that about five billion years ago Earth was extremely hot. As Earth slowly cooled, water vapor in its atmosphere condensed and fell as rain, forming today's oceans. Life appeared in these oceans between 3.9 and 3.5 billion years ago. Since then, millions of species have evolved and then become extinct.



Geologic Time Scale

The four divisions of the geologic time scale span about 4.6 billion years of Earth's history.

The Precambrian

The Precambrian encompasses approximately the first four billion years of the scale. Fossils of prokaryotic cells appear in rocks dated 3.4 billion years old. By the end of the Precambrian, the first eukaryotic cells had evolved.

The Paleozoic Era

The following 300 million years make up the Paleozoic Era. Many plant groups such as ferns and conifers appeared. Animal groups such as worms, insects, fishes, and reptiles evolved.

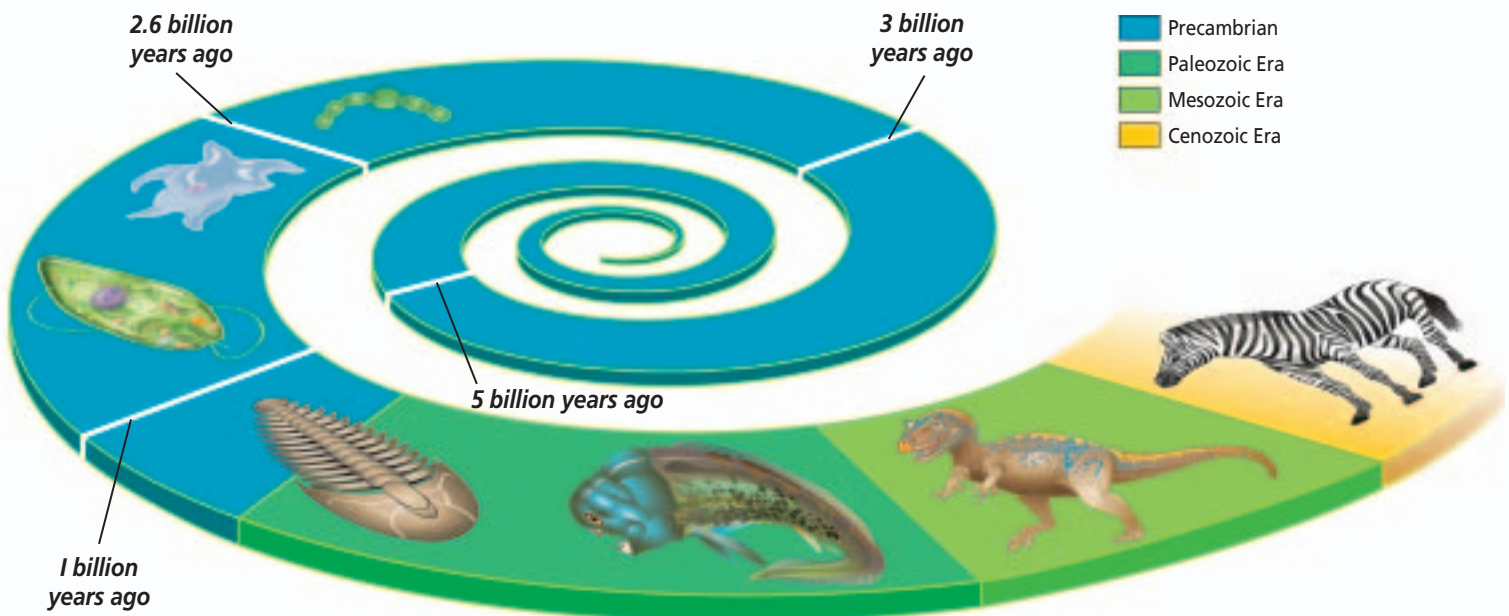
The Mesozoic Era

From 248 million years ago to 65 million years ago, the Mesozoic Era, reptiles diversified, and mammals and flowering plants evolved. The Mesozoic, the Age of Dinosaurs, ended with a rapid extinction of the dinosaurs.

The Cenozoic Era

The current Cenozoic Era, which has encompassed the previous 65 million years, is often referred to as the Age of Mammals. Primates, including humans, evolved during this era.

The geologic time scale illustrates major events that have occurred during Earth's 4.6-billion-year history. Each era is subdivided into smaller time spans called periods.

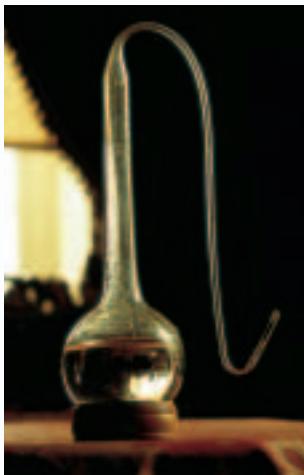


Origin of Life Theories

People once thought that life was able to arise spontaneously from nonliving material. Two scientists, Francesco Redi and Louis Pasteur, designed controlled experiments to try to disprove spontaneous generation. Their experiments convinced scientists to accept the theory of biogenesis—that life comes only from preexisting life.

Modern Ideas About the Origin of Life

Scientific evidence supports the hypothesis that small organic molecules formed from substances present in Earth's early atmosphere and oceans. At some point, nucleic acids must have formed. Then, clusters of organic molecules might have formed protocells that may have evolved into the first true cells.

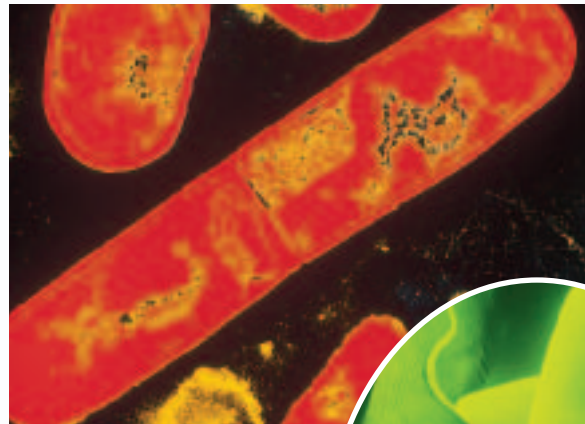


Louis Pasteur disproved the idea of spontaneous generation by conducting experiments using broth in swan-necked flasks like this one.

Heterotrophic, anaerobic prokaryotes were probably the earliest organisms to live on Earth. Chemosynthetic prokaryotes evolved over time, followed by oxygen-producing photosynthetic prokaryotes. As the amount of oxygen in the atmosphere increased, aerobically respiring eukaryotes probably evolved.

Color-enhanced TEM
Magnification: 12 500×

▼ A heterotrophic prokaryote



Color-enhanced SEM
Magnification: 2 800×

Eukaryotic cells, like this *Euglena*, contain organelles, such as mitochondria and chloroplasts, that probably evolved over time from a symbiotic association with prokaryotes.



Focus on History

Pioneers



Lynn Margulis

Two scientists, Stanley Miller and Harold Urey, pioneered work about the origin of Earth's life. Their experiments showed that small molecules can form complex organic materials under conditions that may have existed on early Earth. Other scientists demonstrated how these complex chemicals could form protocells, which are large, organized structures that carry out some activities associated with life, such as growth and division.

The American biologist Lynn Margulis proposed the endosymbiont theory. This theory suggests that cell organelles, such as mitochondria and chloroplasts, may have evolved when small prokaryotes entered larger prokaryotes and began to live symbiotically inside these larger cells.

Evidence of Evolution

Charles Darwin and Alfred Wallace proposed natural selection as a mechanism of evolution. Natural selection occurs because all organisms compete for mates, food, space, and other resources. Such competition favors the survival of individuals with variations that help them compete successfully in a specific environment. Individuals that survive to reproduce can pass their traits to the next generation.

Fossil Evidence

The fossil record provides a record of life on Earth and contains evidence for evolution. Fossils come in many forms, such as imprints, the burrow of a worm, or a mineralized bone. By studying fossils, scientists learn how organisms have changed over time.

Scientists use relative and radiometric dating methods to determine the age of fossils and rocks. Relative dating assumes that in undisturbed layers of rock, the deepest rock layers contain the oldest fossils. Radiometric dating analysis compares the known half-lives of radioactive isotopes to a ratio of the amount of radioactive isotope originally in a rock with the amount of the isotope in the rock today. Fossils over 50 000 years old cannot be radiometrically dated, so the rock around them is dated.

Additional Evidence

Similar anatomical structures, called homologous structures, in different organisms might indicate possible shared ancestry. For example, both vertebrate limbs and developmental stages show how vertebrates might be related. In addition, similarities among the nucleic acid sequences of species provide evidence for evolution. Direct evidence for evolution has been observed in the laboratory when species of bacteria have developed resistance to antibiotics.



Mechanics of Evolution

Evolution occurs when a population's genetic equilibrium changes. Mutations, genetic drift, and migration may slightly disrupt the genetic equilibrium of large populations, but they will greatly alter that of small populations. Natural selection affects the genetic equilibrium of all populations.

Three Patterns of Evolution

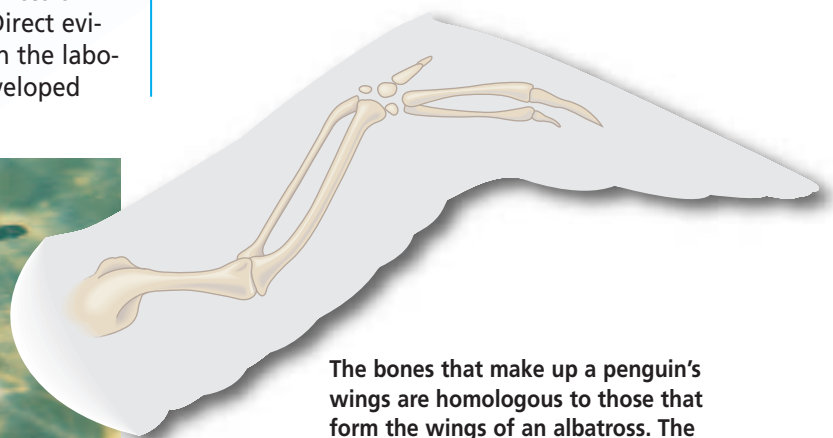
Three patterns of natural selection lead to speciation. Stabilizing selection favors the survival of a population's average individuals for a feature. Directional selection naturally selects for an extreme feature. Disruptive selection eventually produces two populations, each with one of a feature's extreme characteristics.

Primate Evolution

Primates are a grouping of mammals with adaptations such as binocular vision, opposable thumbs, and mobile skeletal joints. These adaptations help arboreal animals survive in forest trees, where all primates may have originally lived and where most primates still live.

There are two categories of primates: the strepsirrhines, including lemurs and aye-ayes, and the haplorhines, including humans, apes, tarsiers, and monkeys. Monkeys are subdivided further into two groups that are called Old World monkeys and New World monkeys.

Primates first appear in the fossil record in the Cenozoic Era. Fossils indicate that increasing brain size and bipedal locomotion are the two major trends in primate evolution.



The bones that make up a penguin's wings are homologous to those that form the wings of an albatross. The forelimb bones of four-legged vertebrates are also homologous.



Unlike most Old World monkeys, New World monkeys, such as this howler monkey, have prehensile tails that are used as a fifth limb.

Human Ancestry

Fossils of possible human ancestors called *Australopithecines* were discovered in Africa and date from approximately 4 million years ago. They show that these ancestors were bipedal and climbed trees.

After examining more recently discovered hominid fossils, paleoanthropologists suggest that the increasing efficiency of bipedal locomotion, the decreasing size of jaws and teeth, and increasing brain size were directions of human evolution.

The appearance of both the genus *Homo* and stone tools coincides in the fossil record about 2.5 million years ago. The use of fire, tools, language, and ceremonies developed in later *Homo* species.

Organizing Life's Diversity

Biologists use a classification system to study and communicate about both the millions of species living on Earth today and the many extinct species represented by fossils. Although Aristotle produced the first system of classification, Linnaeus developed the basic structure of the present-day classification system. Linnaeus also developed a naming system, termed binomial nomenclature, that is still used today.

Today's classification uses a hierarchy of taxa to classify organisms. From largest to smallest, this hierarchy is kingdom, phylum or division, class, order, family, genus, and species. The most useful systems of classification show evolutionary relationships among species.

Six Kingdoms of Classification

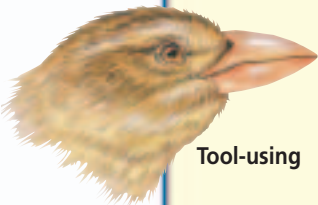
Species are classified into one of six kingdoms. Prokaryotes belong to Kingdom Archaeobacteria or Kingdom Eubacteria. Kingdom Protista contains the eukaryotes that lack complex organ systems and live in moist environments. Kingdom Fungi includes heterotrophic eukaryotes that absorb nutrients. Multicellular autotrophs with complex organ systems are placed in Kingdom Plantae. Kingdom Animalia includes multicellular heterotrophs.

FOCUS ON ADAPTATIONS

Adaptive Radiation in Galápagos Finches

The finches in the Galápagos Islands are an example of the rapid development of a species. It has been proposed that the 13 species of Galápagos finches evolved from one ancestral species of finches that arrived from South America and colonized the newly formed habitats of these volcanic islands.

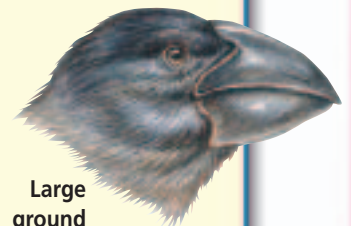
The adaptive radiation of finch species occurred as the original finch population adapted to the different niches found in the islands. The pressures of natural selection produced different species, each with their own feeding and habitat adaptations. Six species are shown here.



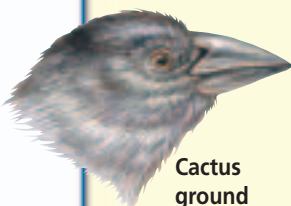
Tool-using



Warbler



Large ground



Cactus ground



Vegetarian



Insectivorous



TEST-TAKING TIP

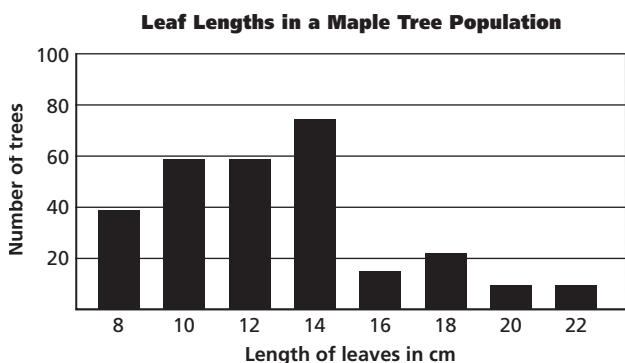
Prepare for the Test

Find out what the conditions will be for taking the test. Is it timed? Will you be allowed a break? Know these things in advance so that you can practice taking tests under the same conditions.

Part 1 Multiple Choice

- Which dating method relies on the position of rock layers?
 - radiometric
 - relative
 - absolute
 - morphology
- Which of the following was proposed by Charles Darwin?
 - endosymbiont hypothesis
 - biogenesis
 - natural selection
 - experimentation
- Multicellular heterotrophs without cell walls are placed in Kingdom _____.
 - Protista
 - Fungi
 - Plantae
 - Animalia

Use the following graph to answer questions 4–6.



- What was the range of leaf lengths?
 - 14 cm
 - 8–22 cm
 - 20–100 cm
 - 10–14 cm

- Which leaf length occurred most often?
 - 8 cm
 - 12 cm
 - 14 cm
 - 6 cm
- What type of evolutionary pattern does the graph most closely match?
 - artificial selection
 - stabilizing selection
 - disruptive evolution
 - directional evolution

Use the following table to help you answer questions 7 and 8.

Some Types of Fossils	
Fossil Type	Description
Trace fossil	Structure in sediment that is indirect evidence of an organism
Mold	Empty space in rock that forms when a shell or other part of an organism decays or dissolves
Cast	Minerals fill a mold to make a replica.
Petrified/permineralized fossils	Minerals replace hard parts or fill pores.
Preserved in amber or frozen in permafrost	Original soft parts of organisms often preserved

- An empty space in a limestone that has the shape of a clam shell is a _____.
 - mold
 - cast
 - trace fossil
 - petrified fossil
- A mark on the surface of a layer of sedimentary rock that was made by a trilobite resting on the bottom of the sea is a _____.
 - mold
 - cast
 - trace fossil
 - fossil in amber

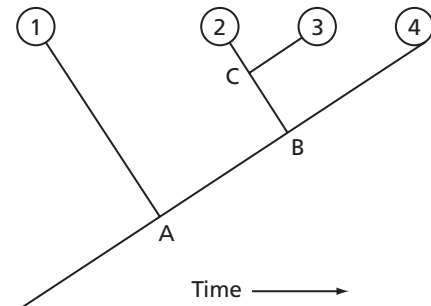
Read the following paragraph and use the diagram to answer questions 9 and 10.

The diagram below represents a cross section of undisturbed rock layers and the species of fossils found in each layer. Use the diagram to answer the following questions.

A	Species 4 & 5
B	Species 3 & 4
C	Species 1 & 2 & 3
D	Species 1 & 2
	Species 1

9. Which environment appears to be most diverse?
 - A. environment A
 - B. environment B
 - C. environment C
 - D. environment D
10. Which species survived the longest in this area?
 - A. species 5
 - B. species 3
 - C. species 2
 - D. species 1

Use the following diagram to answer questions 11–13.



11. Which organism's ancestors diverged first?
 - A. 1
 - B. 2
 - C. 3
 - D. 4
12. Which organism has traits A and B, but not C?
 - A. 1
 - B. 2
 - C. 3
 - D. 4
13. Which organism most recently diverged?
 - A. 1
 - B. 2
 - C. 3
 - D. 4

Part 2 Constructed Response/Grid In

Record your answers on your answer document.

14. **Open Ended** Describe the types of organisms that existed in the Mesozoic Era. In the Cenozoic Era.
15. **Open Ended** Explain how natural selection might be a mechanism of evolution.
16. **Open Ended** Why do biologists classify organisms?

The following diagram illustrates a cross section through a sequence of rock units. Use the diagram to answer questions 17 and 18.

Limestone B containing oyster fossils
Sandstone containing fern fossils
Limestone A containing fish fossils

17. **Open Ended** If the sequence is undisturbed, which rock layer is the oldest? Which is the youngest? Explain your answer.
18. **Open Ended** Describe the environments in which the rock layers were deposited. Explain the evidence for your answer.

